TWO-WEEK LOAN COPY
This is a Library Circulating Copy
which may be borrowed for two weeks.

UCRL-17492
c.2 repl.

University of California

Ernest O. Lawrence Radiation Laboratory

B-L SPACE AND GEOMAGNETIC-FIELD MODELS

Peter J. Lindstrom and Harry H. Heckman

September 19, 1967

Berkeley, California

UCRL-17492 c.2 repl.

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Submitted to
Journal of Geophysical Research

UCRL-17492
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

B - L SPACE AND GEOMAGNETIC-FIELD MODELS

Peter J. Lindstrom and Harry H. Heckman

September 19, 1967

B - L SPACE AND GEOMAGNETIC FIELD MODELS

Peter J. Lindstrom

Space Sciences Laboratory
University of California
Berkeley, California

and

Harry H. Heckman

Lawrence Radiation Laboratory
University of California
Berkeley, California

September 19, 1967

ABSTRACT

We have intercompared geomagnetic field models in B-L space for $0.20 \leq B \leq 0.24$ gauss and $1.2 \leq L \leq 1.8$ R_e (earth radii). Three field models were selected because of their general usage in the analysis of trapped radiation data: Jensen and Whitaker (512 coefficient); Jensen and Cain (48 coefficient); GSFC (9/65)(99 coefficient). These models were compared with the GSFC (12/66) field model (121 coefficient). The geographic coordinates of constant B-L trajectories were computed using the GSFC (12/66) field in both the southern and northern hemispheres. At each geographical point along the trajectories thus defined, B and L values were recalculated using different geomagnetic field models. We find that variations in B-L space of the 48- and 512-coefficient models with respect to the 121-coefficient model are great enough to cause significant ambiguities in flux contours of the trapped radiation. We also have examined the effects of temporal variations of the geomagnetic field on B-L space. The uncertainties in the proton flux contours in B-L

space caused by errors in the field models and time variations of the geomagnetic field demonstrate the need for careful reevaluation of existing data that pertain to possible time variations of inner-belt protons.

INTRODUCTION

Since its inception, B-L space has been used extensively in the study of radiation trapped in the earth's magnetic field. B-L space was developed by [McIlwain, 1961] in order to apply the adiabatic invariants of charged particle motion [Northrop and Teller, 1960] to the azimuthally asymmetric geomagnetic field in a physically meaningful coordinate system. [Stone, 1963] has shown that the B-L coordinates for mirroring particles accurately reflect the invariant shells (I, B_m). Theoretically, B-L space is an accurate space in which particle flux measurements may be reduced and compared. However, a geomagnetic field model must be used in the calculation of B and L, and errors dependent on the model can be significant. If the geomagnetic field model used in calculating B and L does not accurately describe the earth's magnetic field, then a real mirror point trajectory will not be represented by a point in B-L space. In order to study variations of measured particle fluxes in B-L space, it is necessary to know the variations which could be introduced by the generating geomagnetic field model.

A number of geomagnetic field models are available for the calculation of B and L values. We have selected the following four field models for the present study:

1. The Jensen and Whitaker 512-coefficient sphereical-harmonic expansion model (JW) [Jensen and Whitaker, 1960];

2. The Jensen and Cain 48-coefficient model (JC) [Jensen and Cain, 1962];

3. The GSFC (9/65) 99-coefficient model [Hendricks and Cain, 1966];

4. The GSFC (12/66) 121-coefficient model [Cain et al., 1967].

We chose the first three field models because of their use in the analyses of trapped-radiation data. The JW model, for instance, was used in the reduction of the Explorer 4 flux data [McIlwain, 1961]. The JC model is considered to be the standard field model for the interpretation of trapped-particle data [Walt, 1966]. Both the JW and JC models are static, constructed to represent the geomagnetic field in 1955 and 1960 respectively. The GSFC (9/65) model contains first-time derivatives in the first 48 coefficients and is more accurate than the JW and JC models [Hendricks and Cain, 1966]. The GSFC (12/66) field is the latest field model, and was constructed from OGO-2 satellite magnetic-field measurements as well as the data used in the construction of GSFC (9/65). The GSFC (12/66) contains both first- and second-time derivatives in all its coefficients. Actually, there are two sets of coefficients labeled GSFC (12/66) -- Sets I and II. Both sets were constructed in the same manner using semi-independent samples of the same data. We have chosen arbitrarily to use Set I for our study.

We have limited our study to the region in B-L space bounded by $0.20 \leq B \leq 0.24$ gauss and $1.2 \leq L \leq 1.8\ R_e$ (earth radii). The lower portion of the inner radiation belt is contained in this interval of B-L values. The gradient of the trapped-particle flux is large along B in this region [Valerio, 1964], and small errors in the computation of B can result in significant errors in the calculated particle flux. In this

B-L region, ionization and nuclear collision in the atmosphere are the dominant particle loss mechanisms. The solar cycle changes in the atmosphere will affect changes in particle loss rates, and, hence, particle fluxes. Any valid observation of such changes in the particle flux and loss rates with respect to the solar cycle must clearly take account of the accuracy of the flux representations.

Periodic comparisons have been made of various geomagnetic-field models with direct measurements of the earth's magnetic field [Cain, 1965, 1966, 1967]. The results with respect to the four above fields are listed in Table I. The rms errors in Table I are net values over the geomagnetic-field data set and, therefore, do not give direct information about model-dependent errors at any given point in B-L space.

For a direct comparison of the accuracy of the four field models within the range of B-L values we are considering, we obtained, from the U. S. Coast Guard, magnetic-field measurements taken in the region of the South Atlantic anomaly (-60° to 0° longitude, -45° to -15° latitude) for the period 1900 through 1965. These data set contains surface, air, and, for 1965, OGO-2 satellite measurements. We compared the Coast Guard data with field values calculated from the four field models, and we aggregated the differences in three ways:

a) for 1900 through 1963

b) for 1955 through 1963

c) for 1965.

The mean difference and the standard deviation from the mean were computed for these three aggregations. The results appear in Table II.

We did not weight the Coast Guard data with respect to reliability of the types of geomagnetic field measurements. For 1955 through 1963, the GSFC (9/65) and the GSFC (12/66) models describe the anomaly region equally well. For 1900 through 1963 GSFC (12/66) is the best model; the importance of the second time derivatives is clearly evident. Since the OGO-2 satellite data were not used in the generation of the GSFC (9/65) field, the error of GSFC (9/65) with respect to OGO-2 measurements indicates that both the GSFC (9/65) and GSFC (12/66) field models are capable of accurately computing field values in the South Atlantic anomaly for 1965.

The above comparisons of the errors in the magnitude of the geomagnetic field are not, however, a sufficient measure of the model-dependent errors in B-L space. To examine such errors it is necessary to compare the geomagnetic field models over the entire mirror-point trajectory. Since we do not have satellite data that encompass the B-L region of interest at all longitudes, we have, on the basis of the results given in Tables I and II, selected the GSFC (12/66) field model as the reference with which the other models can be compared. Since a point in B-L space represents the trajectory of the mirror points of a particle trapped in the geomagnetic field, it is necessary to compare the models over complete B-L trajectories to reveal the differences that may exist between field models. Our purpose, then, is to compare the fields directly in B-L space.

We have made this comparison by (a) calculating the geographic coordinates at various longitudes for a given point in B-L space in the northern and southern hemispheres, as defined by the GSFC (12/66)

model, and (b) calculating B and L values for these particular geographic coordinates as computed by the other spherical-harmonic field expansions.

Method

Using the GSFC (12/66) field model, we calculated sets of geographic coordinates of B-L trajectories for B values of 0.20 to 0.24 gauss in steps of 0.01 gauss and L values of 1.2 to 1.8 R_e in steps of 0.2 R_e. We generated these sets for the years 1955 to 1975 in 5-year steps for both the northern and southern hemispheres. The geographic contours were calculated for a given B and L value at 10° intervals in longitude, and in the South Atlantic anomaly region at 5- and 2.5° intervals. By holding B, L, and longitude constant and searching for the altitude and latitude, we located geographic coordinates of a B-L trajectory with a variation of the computer program SHELL [Reoderer and Herod, 1966]. For the computation of B and L we used the computer program INVAR, expanding the subroutine NEWMAG to handle the JW coefficients [McIlwain, 1966]. Using the geographic coordinates computed for the sets of B-L trajectories defined by the GSFC (12/66) model, we calculated new B and L values using other field models. In this manner we compared the JW and JC fields with the GSFC (12/66) model, both for the years they represent (1955 for JW, 1960 for JC) and for ten years later; and GSFC (9/65) with GSFC (12/66) for 1955, 1965, and 1975. We used GSFC (12/66) for 1965 as the reference field for an examination of the time dependence of the geomagnetic field. We also compared GSFC (12/66) Set I with Set II of GSFC (12/66) for 1955, and 1975 to determine the internal accuracy of GSFC (12/66). An internal

comparison of GSFC (12/66) Set I with itself indicates that the computations are accurate to within $B = \pm 10\ \gamma$ ($1\gamma = 10^{-5}$ gauss), $L = \pm 0.0005$ R_e.

RESULTS

Using the method described above, we made 560 comparisons between the various field representations for selected B-L points in the interval $0.20 \leq B \leq 0.24$ gauss and $1.2 \leq L \leq 1.8\ R_e$, respectively. We plotted in B-L space a sample of all B-L trajectories which show a deviation from the generating B-L point of more than 100 γ in B or 0.005 R_e in L. Figure 1 is one of these plots. The contour is the trace of B and L values computed using the JC model for the geographic points of the B (0.24)-L (1.4) trajectory defined by the GSFC (12/66) model for 1960. Figure 1 is typical of all of the comparisons we made because there is no function that will transfer a point in B-L space generated by one geomagnetic field model into a point in B-L space generated by another field model, unless the longitude and hemisphere are known. In other words, flux contours in B-L space cannot be corrected for model-dependent errors without knowing where the data were collected. The flux contours in Fig. 1 are 40 to 110-MeV proton flux contours from INJUN 3 [Valerio, 1964] and are given to indicate the possible range of flux values that can be assigned to the same B-L point.

Let us consider a specific example. Assuming that the INJUN 3 flux contours accurately reflect the shape of the proton flux in the inner radiation belt, then the flux at B = 0.24 gauss, L = 1.4 R_e is 30 protons/cm^2-sec (f_0). If proton flux data were collected in the southern hemisphere at 325° longitude and B-L values were calculated using the JC

model, the flux value of f_0 would be assigned to the point B = 0.235 gauss, L = 1.41 R_e. Owing to this (downward) shift in the flux contours, the "expected" flux value at B = 0.24 gauss, L = 1.4 R_e would be approximately 5 protons/cm^2 sec. If in another flight experiment, flux data were collected at 0° longitude in the southern hemisphere, then f_0 would be at B = 0.243 gauss, L = 1.386 R_e, and the flux contour would be shifted (upward) so that the flux expected at B = 0.24 gauss, L = 1.4 R_e would be 75 protons/cm^2 sec. In the two above cases, the apparent 1:15 ratio in flux values at B = 0.24 gauss, L = 1.4 R_e is due only to relative inaccuracies in the JC field model.

In Fig. 2 we show the B-L coordinates as computed by the JC field, given the mirror point trajectory for B = 0.24 gauss, L = 1.4 R_e using the GSFC (12/66) for 1970. If we assume, for the sake of argument, that the flux contours in B-L space are time-independent, then flux data collected at 325° longitude in the southern hemisphere in 1970 and reduced using the JC field, f_0 (= 30), would be shifted such that at B = 0.24 gauss, L = 1.4 R_e, the flux would be 40 protons/cm^2 sec. If these data were to be compared with data collected at the same geographic coordinates in 1960 (Fig. 1), the factor of 8 in the fluxes would be solely due to temporal variations in the geomagnetic field. In Fig. 2, proton-flux data collected in the northern hemisphere at 0° longitude compared with flux collected in the southern hemisphere at 0° longitude will give flux values of 20 and 160 protons/cm^2 sec for the same (JC) B-L points, due only to inaccuracies in the JC field in 1970. Figure 3 is a comparison of the JW model with the GSFC (12/66) model for 1955. By referring to the INJUN 3 proton-flux contours, we note that proton

fluxes at B = 0.24 gauss, L = 1.4 R_E can vary from 5 to 250 protons/ cm^2 sec--variations attributable to relative errors in the JW model only.

Table III gives the maximum deviation in B and L for three examples of B-L points for various field comparisons. The comparison of GSFC (9/65) with GSFC (12/66) confirms the conclusion drawn from the comparisons of these fields with direct geomagnetic-field measurements in the South Atlantic anomaly region--namely, that the two models agree quite well for 1965 but diverge from each other 10 years before or after. The comparisons between JC and GSFC (12/66) show large variations at all B-L points studied in both 1960, the year the JC field model was generated to represent, and 10 years later. The variations between JW and GSFC (12/66) are even larger.

Table III also shows the range of proton-flux values as deduced from the INJUN 3 proton-flux contours, which could be assigned to the same B-L point due to errors in the geomagnetic-field model. We note that the flux variations caused by errors in the JW and JC fields are comparable to the magnitude of flux changes expected over a solar cycle [Blanchard and Hess, 1964].

Large flux variations need not necessarily appear as a large scatter of equal flux values in B-L space measured in a single satellite experiment. In fact, it is possible to have the flux contours well defined. The flux measurements for a given B-L point can be collected only where the satellite orbit intercepts the B-L trajectory. This generally means that the flux measurements for a B-L point are collected only in a small portion of the B-L trajectory. If the geomagnetic field model used in

the B and L calculations is inaccurate, it can sytematically shift B and L in one direction for one experiment and in another direction for another experiment. Comparison of such experiments as to absolute proton flux values can lead to faulty conclusions.

The comparison of GSFC (12/66) for 1965 with GSFC (12/66) for 1955 and for 1975 shows another factor which must be taken into consideration in studies of the temporal changes of the trapped radiation. Figure 4 is a comparison of GSFC (12/66) for 1965 with GSFC (12/66) for 1975 at B = 0.24 gauss, L = 1.4 R_e. The magnitude of the variation in B-L space of the same geographic coordinates over a 10-year period (Fig. 4) shows that the geomagnetic field is dynamic. Trapped radiation flux contours constructed in B-L space can contain significant errors if the field model used does not represent the geomagnetic field at the time the data were collected. An important feature of the time variations of the geomagnetic field with respect to the trapped radiation is the change in altitude of the same B-L trajectory in the South Atlantic anomaly region. Figure 5 shows the B-L trajectories of L = 1.4 R_e, B = 0.22 and 0.24 gauss for 1965 and for 1975. Over a 10-year period the minimum mirror-point altitude at L = 1.4 R_e, B = 0.20 gauss decreases about 70 kilometers. Particles mirroring at the same B and L values will experience a denser atmosphere in 1975 than in 1965. The flux of trapped radiation at L = 1.4 R_e and B = 0.23 gauss will decrease by about a factor of four, and at B = 0.24 gauss will virtually disappear in 10 years, independent of solar activity. The problems introduced by the time dependence of minimum mirror-point altitudes cannot be circumvented by the use of a static field model because of the nature of temporal variations

(Fig. 4). The geomagnetic field must be treated as a dynamic field for any long-range studies and predictions of trapped radiation.

For the field-model comparisons made in our study, we have assumed that the GSFC (12/66) field model is an accurate representation of the geomagnetic field. We have shown that the GSFC (12/66) is the best field model considered both for general geomagnetic-field measurements and for measurements in the South Atlantic anomaly region (Tables I and II). To measure the accuracy of the GSFC (12/66) Set I model, we have compared it with GSFC (12/66) Set II and with GSFC (9/65) for 1965. In the region of B-L space considered, Set I differs from Set II by a maximum of ±25 γ for 1955 and 1965, ±75 γ for 1975, while GSFC (12/66) differs from GSFC (9/65) by a maximum of ±60 γ for 1965.

All the plots of the geomagnetic field comparisons listed in Table III are available in University of California Space Sciences Laboratory Report Series 8 Issue 69, "B-L Space and Geomagnetic Field Models". We have plotted seven B-L points for each intermodel comparison:

1. B = 0.21 gauss, L = 1.2 R_E
2. B = 0.21 L = 1.4
3. B = 0.24 L = 1.4
4. B = 0.21 L = 1.6
5. B = 0.24 L = 1.6
6. B = 0.21 L = 1.8
7. B = 0.24 L = 1.8

These plots can be used in converting flux data in B-L space defined by one geomagnetic-field model into B-L space defined by another field model, provided geographic positions of the flux measurements are known.

CONCLUSION

Model-dependent errors can cause large apparent differences in trapped particle fluxes in B-L space. There is no simple way to transform B-L points of one field model to B-L points of another field model without using the geographic coordinates used in generating the B-L points. Temporal variations of the geomagnetic field alter the geographic positions of mirror-point trajectories. Since the dominant particle-loss mechanisms for the region of B-L space studied are ionization and nuclear collision in the atmosphere, any computation of loss rates, lifetimes, and temporal change of particles in the inner belt strongly depends on the use of an accurate time-dependent geomagnetic-field model. The range of model-dependent errors in B-L space demonstrates the need for careful reevaluation of existing data that pertain to possible time variations of inner-belt particle fluxes.

ACKNOWLEDGMENT

This work was done under the auspices of the U. S. Atomic Energy Commission and the National Aeronautics and Space Administration Contract 9-5249.

REFERENCES

Blanchard, R. C., and W. N. Hess, Solar cycle changes in inner-zone protons, J. Geophys. Res., 69, 3927-3938, 1964.

Cain, J. C., W. E. Daniels, S. J. Hendricks, and D. C. Jensen, An Evaluation of the main geomagnetic field 1940-1962, J. Geophys. Res., 70, 3647-3674, 1965.

Cain, J. C., Models of the Earth's magnetic field, in radiation trapped in the Earth's magnetic field, pp 7-25, DeReidel Publishing Company, Dordrecht, Holland, 1966.

Cain, J. C., S. J. Hendricks, R. A. Langel, and W. V. Hudson, A proposed model for the international geomagnetic reference field, 1965, Preprint, Goddard Space Flight Center, Greenbelt, Maryland, 1967.

Hendricks, S. J., and J. C. Cain, Magnetic field data for trapped particle evaluations, J. Geophys. Res., 71, 346-347, 1966.

Jensen, D. C., and J. C. Cain, An interim geomagnetic field, J. Geophys. Res., 67, 3568-3569, 1962.

Jensen, D. C., and W. A. Whitaker, A spherical harmonic analysis of the geomagnetic field, J. Geophys. Res., 65, 2500, 1960.

McIlwain, C. E., Coordinates for mapping the distribution of geomagnetically trapped particles, J. Geophys. Res., 66, 3681-3692, 1961.

McIlwain, C. E., private communication, 1966.

Northrop, T. G., and E. Teller, Stability of the adiabatic motion of charged particles in the Earth's field, Phys. Rev., 117 215-225, 1960.

Reoderer, J. G., and J. V. Herod, A computational model for geomagnetically trapped particle shells and kinematic parameters, Air Force Weapons Laboratory Technical Report No. AFWL-TR-66-78, Air Force Systems Command, Kirtland Air Force Base, New Mexico 1966.

Stone, E. C., The physical significance and application of L_1B_0 and R_0 to geomagnetically trapped particles, J. Geophys. Res., 68, 4157-4166, 1963.

Valerio, J., Protons from 40 to 110 MeV observed on Injun 3, J. Geophys. Res. 69, 4949-4958, 1964.

Walt, M., Future magnetic field for B-L space, in radiation trapped in the Earth's magnetic field, p. 62, DeReidel Publishing Company, Dordrecht, Holland, 1966.

Table I. Root-mean-square deviation between unweighted survey data for 1945-1965 and computed values.

Field model	rms error (γ)[a]
JW	~800[b]
JC	440[c]
GSFC (9/65)	220[d]
GSFC (12/66)	122[e]

[a] $\gamma = 10^{-5}$ gauss.

[b] Estimate from our B-L comparisons.

[c] Cain, et al., 1965.

[d] This rms error was derived from an earlier version of the GSFC (9/65) model, namely, GSFC (7/65). The GSFC (7/65) model contains an external-field component, whereas GSFC (9/65) does not. Each of these models was constructed from the same data set and have the same accuracies [Cain, 1966].

[e] Rms computation with survey data for 1900 through 1965. [Cain, et al., 1967].

Table II. Mean deviation and standard deviation between unweighted magnetic survey data and computed values in the region of the South Atlantic anomaly.

Field model	Number of data points	Mean deviation (γ)	Standard deviation (γ)
Surface and air 1900-1963 geomagnetic-field measurements			
JW	1369	-155.6	1056.3
JC		-560.2	892.0
GSFC (9/65)		297.0	477.6
GSFC (12/66)		-1.2	180.0
Surface and air 1955-1963 geomagnetic-field measurements			
JW	825	461.2	524.4
JC		-20.4	301.5
GSFC (9/65)		15.2	177.2
GSFC (12/66)		9.7	171.9
OGO-2 satellite measurements			
GSFC (9/65)	1330	7.1	14.5
GSFC (12/66)		1.8	7.2

Table III. Geomagnetic comparisons of various field model configurations for three B-L points.

B_1 (gauss)	L_1 (R_e)	Year for GSFC(12/66) used in generating B_1-L_1 trajectory	Field for evaluating B-L at geographic coordinates of B_1-L_1 trajectory	Range of differences $\pm\Delta L$, between L and L_1		Range of differences $\pm\Delta B$, between B and B_1		Range of INJUN 3 proton fluxes (J = particles/cm^2 sec allowed by errors in B-L space	
				$+\Delta L$ ($10^{-4} R_e$)	$-\Delta L$ ($10^{-4} R_e$)	$+\Delta B$ (γ)	$-\Delta B$ (γ)	J max	J min
0.21	1.2	1955	GSFC (9/65) for 1955	16	16	61	36	160	130
		1965	GSFC (9/65) for 1965	16	12	37	39	160	140
		1975	GSFC (9/65) for 1975	39	62	149	84	170	130
		1960	JC	91	94	122	208	190	90
		1970	JC	148	190	545	222	310	110
		1955	JW	69	127	685	378	290	70
		1965	JW	77	217	739	440	350	70
		1965	GSFC (12/66) for 1955	75	158	504	107	300	120
		1965	GSFC (12/66) for 1975	199	62	105	600	170	40
0.24	1.4	1955	GSFC (9/65) for 1955	30	33	105	89	35	25
		1965	GSFC (9/65) for 1965	26	16	45	42	30	30
		1975	GSFC (9/65) for 1975	106	83	163	160	40	20
		1960	JC	135	148	416	544	75	5
		1970	JC	323	358	830	211	180	20
		1955	JW	213	312	1028	596	170	5
		1965	JW	230	385	1366	662	325	0
		1965	GSFC (12/66) for 1955	227	323	628	181	140	20
		1965	GSFC (12/66) for 1975	379	226	181	613	45	0
0.24	1.8	1955	GSFC (9/65) for 1955	39	47	119	63	125	110
		1965	GSFC (9/65) for 1965	32	31	51	79	120	110
		1975	GSFC (9/65) for 1975	165	117	288	285	140	95
		1960	JC	121	192	603	584	160	80
		1970	JC	444	468	1189	108	200	105
		1955	JW	363	440	706	605	170	80
		1965	JW	274	439	1110	678	200	75
		1965	GSFC (12/66) for 1955	350	433	693	174	160	105
		1965	GSFC (12/66) for 1975	481	377	180	816	130	75

FIGURE LEGENDS

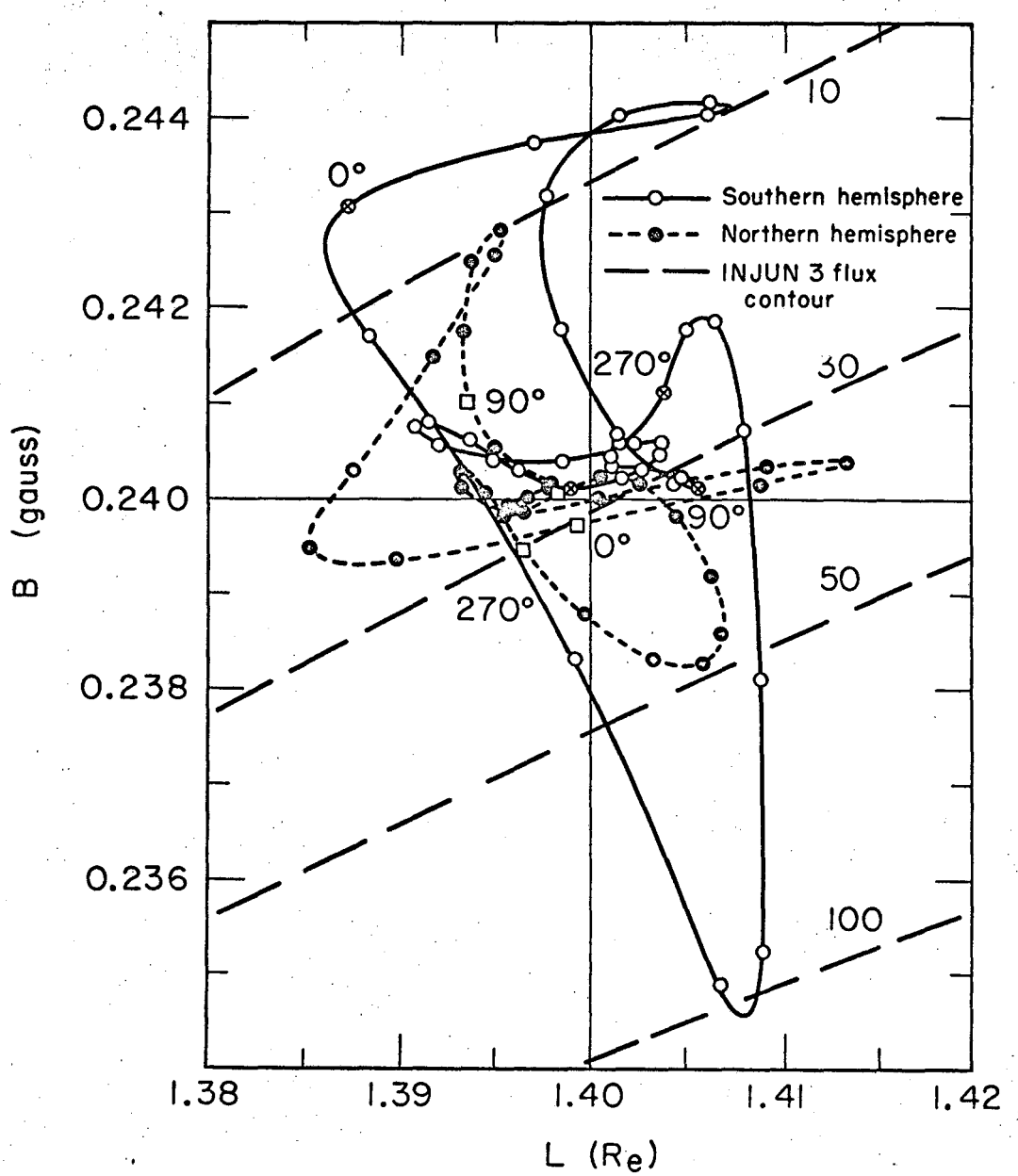
Fig. 1. B and L values computed using the JC field model for the geographic coordinates of the B = 0.24 G, L = 1.4 R_e trajectory defined by the GSFC (12/66) field for 1960. Longitude is indicated at each 10° interval.

Fig. 2. B and L values computed using the JC field model for the geographic coordinates of the B = 0.24 G, L = 1.4 R_e trajectory defined by the GSFC (12/66) field for 1970. Longitude is indicated at each 10° interval.

Fig. 3. B and L values computed using the JW field model for the geographic coordinates of the B = 0.24 G, L = 1.4 R_e trajectory defined by the GSFC (12/66) field for 1955. Longitude is indicated at each 10° interval.

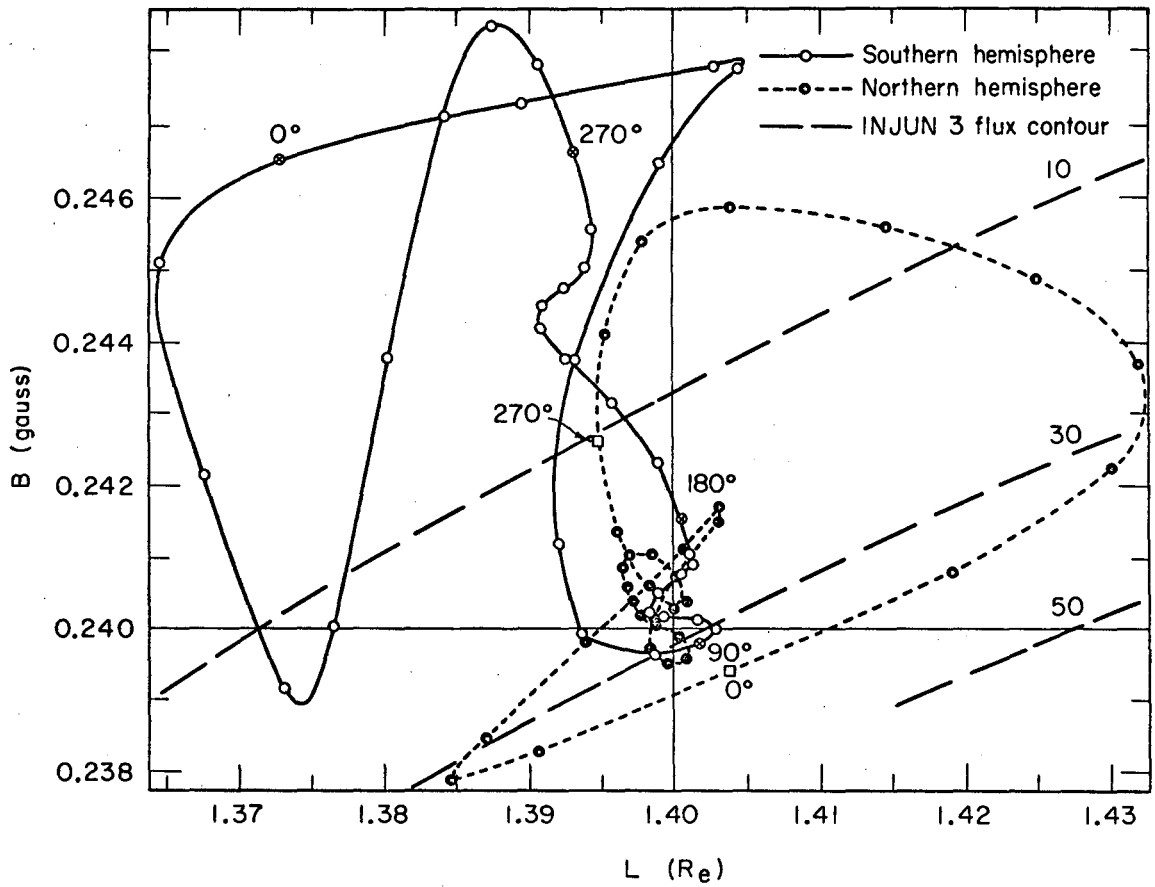
Fig. 4. B and L values computed using the GSFC (12/66) field for 1975 for the geographic coordinates of the B = 0.24 L = 1.4 R_e trajectory defined by the GSFC (12/66) field for 1965. Longitude is indicated at each 10° interval.

Fig. 5. Altitudes of the B-L trajectories in the region of the South Atlantic anomaly computed using the GSFC (12/66) field for 1965 and 1975.



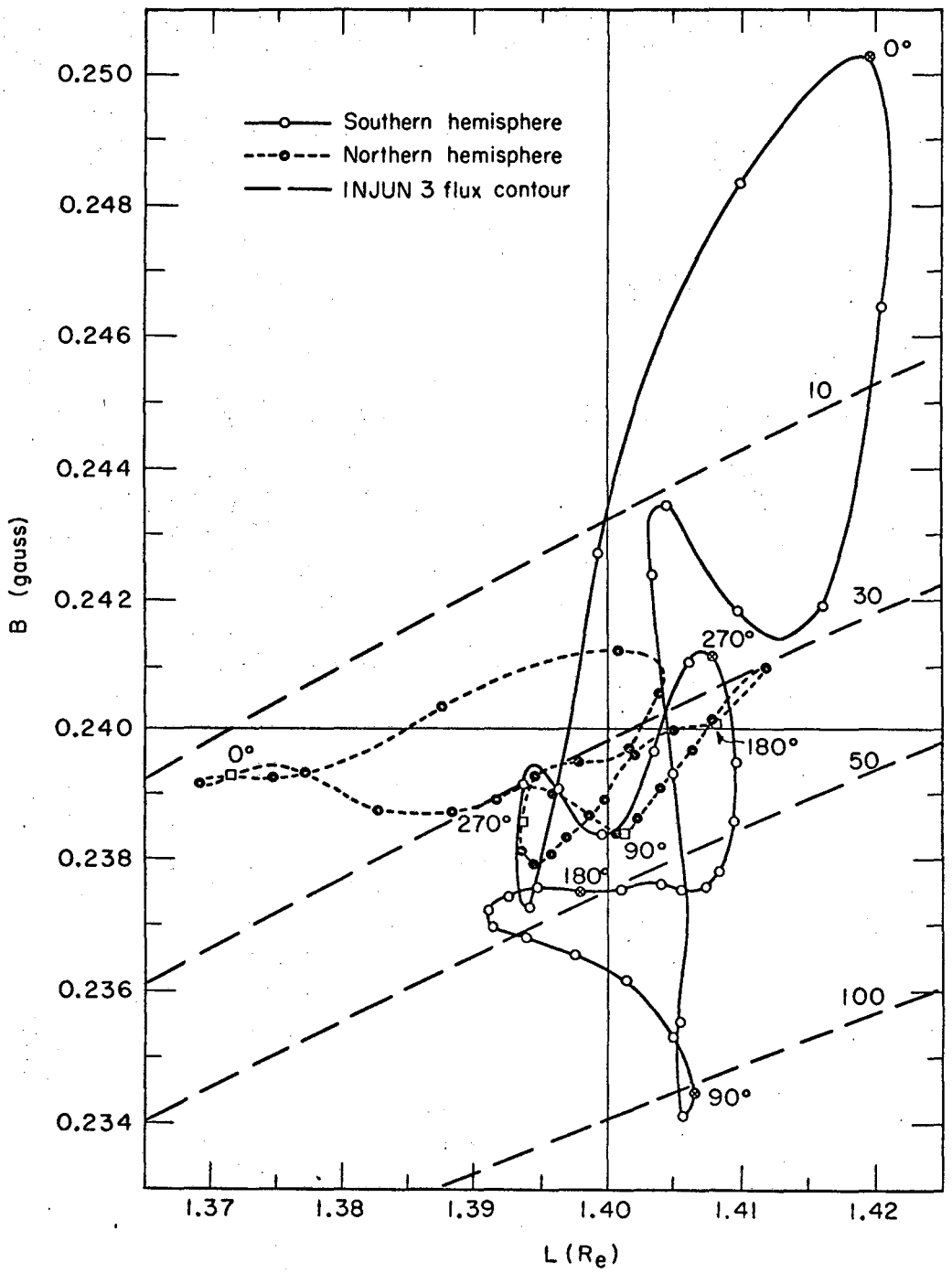
XBL 670-5311

Fig. 1



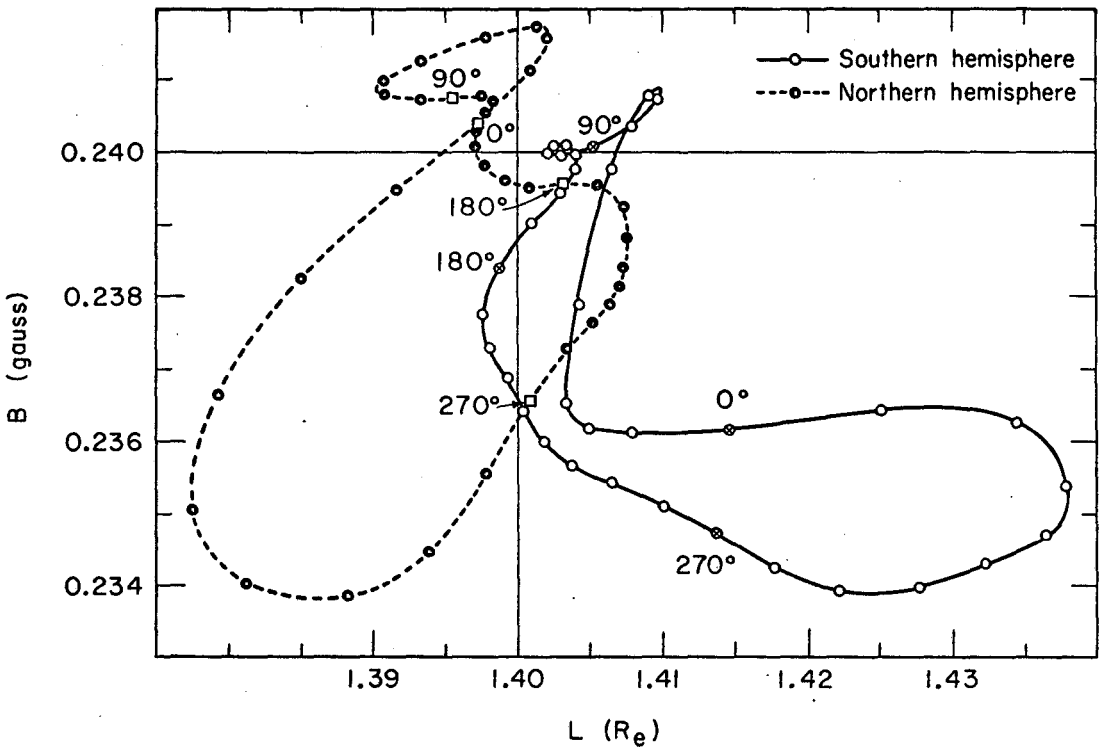
XBL 670-5312

Fig. 2.



XBL 670 - 5313

Fig. 3



XBL670-5314

Fig. 4

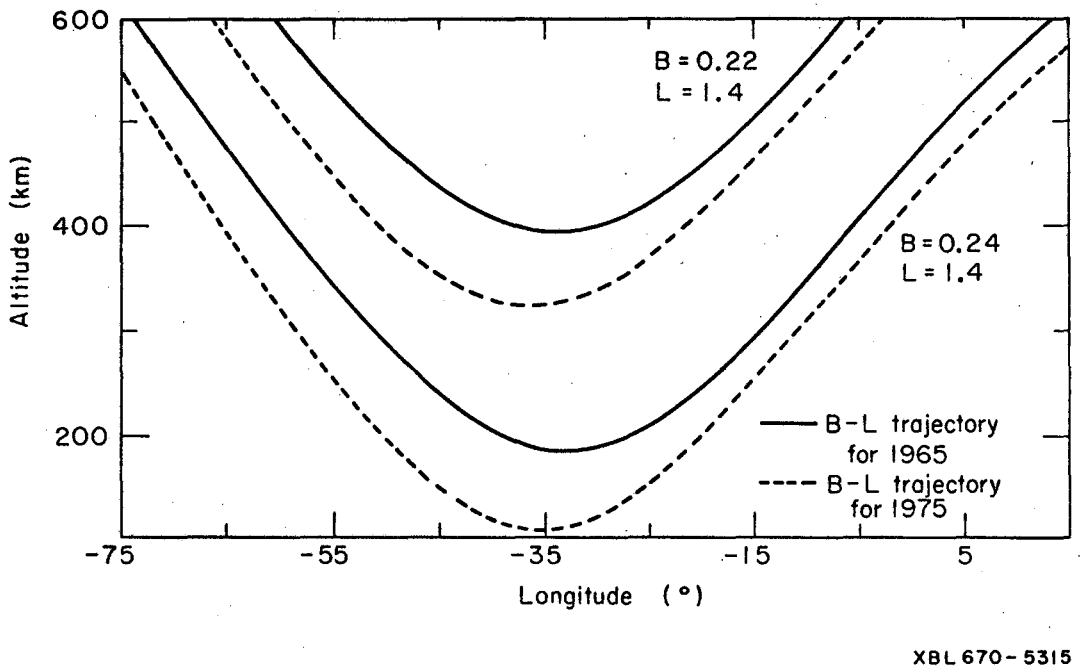

600
400
200
Altitude (km)
-75
-55
-35
-15
5
Longitude (°)
B = 0.22
L = 1.4
B = 0.24
L = 1.4
B-L trajectory for 1965
B-L trajectory for 1975
XBL 670-5315

Fig. 5

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.